

**NEW UTILITY PATENT APPLICATION
TRANSMITTAL***(Only for new nonprovisional applications under 37 C.F.R. 1.53(b))*Docket No.
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submission**TO THE ASSISTANT COMMISSIONER FOR PATENTS****Box Patent Application
Washington, D.C. 20231**

Transmitted herewith for filing under 35 U.S.C. 111(a) and 37 C.F.R. 1.53(b) is a new utility patent application for an invention entitled:

DATA RECORDING CLOCK SIGNAL GENERATOR

and invented by:

Toshihiro Shigemori

IF A CONTINUATION APPLICATION, check appropriate box and supply requisite information:☐

Continuation

☐

Divisional

☐

Continuation-in-part (CIP) of prior application No.:

Enclosed are:

Application Elements

1. ☒ Filing fee as calculated and transmitted as described below
2. ☒ Specification having 56 pages(s) and including the following:
 - a. ☒ Descriptive title of the invention
 - b. ☐ Cross references to related applications *(if applicable)*
 - c. ☐ Statement regarding Federally-sponsored research/development *(if applicable)*
 - d. ☐ Reference to microfiche appendix *(if applicable)*
 - e. ☒ Background of the invention
 - f. ☒ Brief summary of the invention
 - g. ☒ Brief description of the drawings *(if drawings filed)*
 - h. ☒ Detailed description
 - i. ☒ Claims as classified below
 - j. ☒ Abstract of the disclosure

Application Elements (continued)

3. ☒ Drawing(s) (when necessary as prescribed by 35 U.S.C. 113)
☒ Formal ☐ Informal Number of sheets: 13
4. ☒ Oath or Declaration
a. ☒ Newly executed (original or copy) ☐ Unexecuted
b. ☐ Copy from a prior application (37 C.F.R. 1.63(d) (for continuation/divisional applications only)
c. ☒ With Power of Attorney ☐ Without Power of Attorney
5. ☐ Incorporation by reference (usable if Box 4b is checked)
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. ☐ Computer program in microfiche
7. ☐ Genetic sequence submission (if applicable, all must be included)
a. ☐ Paper copy
b. ☐ Computer readable copy
c. ☐ Statement verifying identical paper and computer readable copies

Accompanying Application

8. ☒ Assignment papers (cover sheet & document(s))
9. ☐ 37 C.F.R. 3.73(b) statement (when there is an assignee)
10. ☐ English translation document (if applicable)
11. ☐ Information Disclosure Statement/PTO-1449 ☐ Copies of IDS citations
12. ☐ Preliminary Amendment
13. ☒ Acknowledgment postcard
14. ☐ Certified copy of priority document(s) (if foreign priority is claimed)
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16. ☐ Small Entity statement(s) -- # submitted _____ (if Small Entity status claimed)

Accompanying Application (continued)

- 17.
- ☐
- Additional enclosures (please identify below):

Fee Calculation and Transmittal

The filing fee for this utility patent application is calculated and transmitted as follows:

☒ Large Entity ☐ Small Entity

<u>CLAIMS AS FILED</u>					
For	# Filed	# Allowed	# Extra	Rate	Fee
Total Claims	6	- 20 =		x \$18.00	
Independent Claims	3	- 3 =		x \$78.00	
Multiple Dependent Claims (check if applicable) <input type="checkbox"/>					
Other Fees (specify purpose): Assignment Recordation fee					\$40.00
BASIC FEE					\$690.00
TOTAL FILING FEE					\$730.00

☒ A check in the amount of \$730.00 to cover the total filing fee is enclosed.☒ The Commissioner is hereby authorized to charge and Deposit Account No. 4 - 1073 as described below. A duplicate copy of this sheet is enclosed.☐ Charge the amount of _____ as filing fee.☒ Credit any overpayment.☒ Charge any additional filing fees required under 37 C.F.R. 1.16 and 1.17.☐ Charge the issue fee set in 37 C.F.R. 1.18 at the mailing of the Notice of Allowance, pursuant to 37 C.F.R. 1.31(b).

Dated: July ¹²/₁₃, 2000

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SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT I, TOSHIHIRO SHIGEMORI, a citizen of Japan residing at Kanagawa, Japan have invented certain new and useful improvements in

DATA RECORDING CLOCK SIGNAL GENERATOR

of which the following is a specification:-

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BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a data recording clock signal generator that generates a recording clock signal used for recording data on a recording medium, such as an optical disk or hard disk, in a data recording device.

2. Description of the Related Art

Known recording media having a data recording track wobbled by a wobble signal having predetermined frequency components include optical disks, such as CD-R, CD-RW, DVD-R, and DVD-RAM. Japanese Laid-Open Patent Application Nos. 10-293926 and 11-66563 each disclose a data recording clock signal generator that generates a recording clock signal synchronous with a wobble signal of an optical disk.

A rewritable optical disk has a drawback that repeated recording on the same spot makes the recording mark and its vicinity deteriorate due to thermal stress, and precise mark recording cannot be performed on that spot when a different signal is recorded. To avoid such a situation, Japanese Patent Publication No. 8-10489 and Japanese Laid-Open Patent Application No. 10-3667 disclose an optical disk recording method and an optical disk device in which the recording starting point is

made variable so that the use of one particular spot is prevented, and the disk material can be used a greater number of times.

Also, Japanese Laid-Open Patent Application No.

5 10-69646 discloses a data recording clock signal generator that generates a recording clock signal synchronous with a wobble signal on which address information and other signals are phase-modulated and superimposed.

10 FIG. 1 is a block diagram showing an example structure of a conventional optical disk driving device.

An optical disk 1 has a data recording track wobbled by a wobble signal having prescribed frequency components.

15 FIG. 2 shows the structure of wobbled data recording track on the optical disk 1.

A land portion indicating the locations of the track is wobbled in accordance with address information, and the address information and a synchronizing signal
20 are modulated and superimposed on the wobble signal.

In the conventional optical disk driving device shown in FIG. 1, an optical pickup (PU) 2 emits a laser beam onto a data recording track on the optical disk 1. The laser beam reflected from the track on the
25 optical disk 1 is returned to the optical pickup 2, and

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is converted into an electric signal by a detector in the optical pickup 2.

An amplifier 3 amplifies the electric signal detected by the optical pickup 2 and outputs a reproducing signal RF corresponding to data recorded on the optical disk 1 and a wobble signal WBL corresponding to the wobble of the track. The reproducing signal RF is detected when the data is reproduced, and the wobble signal WBL is detected when the data is either recorded or reproduced.

A recording clock generator circuit 4 generates a recording clock signal WCLK which is synchronous with the wobble signal WBL.

FIG. 3 is a block diagram showing an example structure of the conventional recording clock generator circuit shown in FIG. 1.

The recording clock generator circuit 4 is constituted by a PLL (Phase-Locked Loop) circuit.

A phase comparator 41 compares the phase of a wobble signal WBL with the phase of a signal obtained by dividing the frequency of a recording clock signal WCLK at a predetermined frequency dividing rate by a frequency divider 45.

The output of the phase comparator 41 is converted into a voltage signal by a charge pump 42,

smoothed by a filter 43, and then inputted into a VCO (Voltage Controlled Oscillator).

The frequency of the output clock of the VCO, which is the recording clock signal WCLK, is controlled by an input voltage. As a result, the phase of the recording clock signal WCLK becomes synchronous with the wobble signal WBL.

Now referring back to FIG. 1, a synchronous detector circuit 5 and an address decoder 6 of the conventional optical disk driving device detect the
10 synchronizing signal and the address information, respectively, superimposed on the wobble signal.

When data recording is carried out, a data encoder 8 synchronizes with the recording clock signal WCLK to perform a predetermined modulation process on the recording data.

An LD driver 9 modulates the strength of laser beams emitted from the optical pickup 2 in accordance with the modulated recording data. As a result, the data recording can be carried out in synchronization with the wobble signal of the data recording track.

According to the technique disclosed in Japanese Patent Publication NO. 8-10489, however, a plurality of analog delay circuits are required for obtaining random recording starting points, resulting in

In the conventional recording clock generating circuit, the phase of the recording clock signal WCLK is constantly synchronous with the wobble signal WBL, as

5 long as the wobble signal is properly detected. However,
minor defects might exist on the optical disk, or dirt
or dust might stick to the surface of the optical disk.
At the locations corresponding to those defects or the
areas to which dirt or dust sticks, the wobble signal is
10 lost, and cannot be detected properly.

In the recording clock generating circuit constituted by the conventional PLL circuit, a small loss of the wobble signal can be ignored, and the phase synchronization between the wobble signal and the recording clock signal can be maintained thanks to a so-called flywheel effect of the PLL. However, if there is a large loss of the wobble signal, a phase shift is caused between the wobble signal and the recording clock signal. After the loss, the phase of the recording clock signal is shifted by a whole number of cycles of the wobble signal. This situation is called a bit slip.

When there is a bit slip in the recording clock signal, the phase difference between the wobble signal and the recording clock signal cannot be compensated, and data recording is performed at

locations deviated from predetermined locations. If new data recording is started after data recording is completed in one sector, with a bit slip remaining in the recording clock signal, data overlapping or unnecessary blank is caused at the connecting portions between the previous recording data and the new recording data. In such a situation, the data recorded in the vicinity of the connecting portion is not properly reproduced.

10 In the case where address information and other signals are phase-modulated and then superimposed on a wobble signal on an optical disk (as disclosed in Japanese Laid-Open Patent Application No. 10-69646, for instance), a drastic change occurs in the phase of the wobble signal due to the phase modulation, and a phase shift is caused between the wobble signal and the recording clock signal.

SUMMARY OF THE INVENTION

20 It is a general object of the present invention to provide a data recording clock signal generator in which the above-mentioned problems are eliminated.

A first specific object of the present invention is to provide a recording clock generating

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circuit with which the recording starting point can be made variable without the use of analog delay circuits, and which can be produced at a lower cost.

5 A second specific object of the present invention is to provide a recording clock generating circuit which can restore recording data at a predetermined location by compensating a phase shift between a wobble signal and a recording clock signal when a bit slip occurs in the recording clock signal due
10 to a loss of the wobble signal.

A third specific object of the present invention is to provide a recording clock generating circuit that generates a recording clock stably synchronous with a wobble signal even in a case where
15 address information and other signals are phase-modulated and superimposed on the wobble signal on an optical disk.

The first specific object of the present invention is achieved by a data recording clock signal
20 generator that generates a recording clock signal synchronous with a wobble signal used for recording data on an optical disk having a data recording track wobbled by the wobble signal having predetermined frequency components. This data recording clock signal generator
25 comprises:

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a recording clock signal dividing unit that generates a divided clock signal obtained by dividing the frequency of the recording clock signal;

10 a frequency control signal generating unit
that generates a frequency control signal based on the
phase difference signal generated by the phase
difference signal generating unit; and

In this data recording clock signal generator,
the recording clock signal dividing unit includes a
frequency dividing rate setting unit that sets a
reference frequency dividing rate and a frequency
dividing rate different from the reference frequency
dividing rate, following predetermined procedures.

25 With the above data recording clock signal

generator, the phase relationship between the wobble
signal and the recording clock signal is varied with the
frequency dividing condition setting value, so that the
phase relationship between the wobble signal and the
5 recording clock signal can be changed by a smaller unit
than one cycle of the recording clock signal.

In the above data recording clock signal
generator, the frequency dividing rate setting unit is
further provided with a rate selecting unit that changes
10 the order of combinations of the reference frequency
dividing rate and the different frequency dividing rate
every time data recording is performed on the optical
disk.

Since the frequency dividing setting value is
15 randomly selected every time data recording is performed
on the optical disk, the phase relationship between the
wobble signal and the recording clock signal is randomly
varied, thereby preventing repeated use of the same spot
on the disk material. Accordingly, the disk material
20 can be repeatedly used a greater number of times.
Furthermore, since the recording starting point can be
randomly changed without the use of analog delay
circuits, the optical disk driving device can be
produced at a lower cost.

25 The second specific object of the present

a synchronous detection unit that detects a synchronizing signal superimposed on the wobble signal;

5 a synchronous relationship judgment unit that judges the synchronous relationship between the detected synchronizing signal and recording data to be recorded on the optical disk; and

20 With the data recording clock signal generator,
the recording clock signal can restore the recording
data at a predetermined location by compensating the
phase shift between the wobble signal and the recording
clock signal even when a bit slip occurs in the
25 recording clock signal due to a loss of the wobble

signal.

The third specific object of the present invention is achieved by a data recording click signal generator that generates a recording clock signal

5 synchronous with the wobble signal used for recording data on an optical disk having a data recording track wobbled by the wobble signal, which has predetermined frequency components, and on which address information and a synchronizing signal are phase-modulated and

10 superimposed. This data recording clock signal generator comprises:

- a wobble signal extracting unit that extracts the wobble signal;
- a recording clock signal dividing unit that

15 generates a divided clock signal obtained by dividing the frequency of the recording clock signal;

- a phase difference signal generating unit that generates a phase difference signal as a result of a phase comparison between the wobble signal and the

20 divided clock signal;

- a frequency control signal generating unit that generates a frequency control signal based on the phase difference signal generated by the phase difference signal generating unit;

25 a recording clock signal generating unit that

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generates the recording clock signal having a frequency controlled in accordance with the frequency control signal generated by the frequency control signal generating unit; and

5 a masking unit that prevents the phase difference signal generating unit from generating the phase difference signal at any timing close to the timing when either the address information or the synchronizing signal is phase-modulated on the optical
10 disk.

With this data recording clock signal generator, the operation of the phase comparator is masked in a region where a drastic change occurs in the phase of the wobble signal due to phase modulation.
15 Accordingly, no phase shift occurs between the wobble signal and the recording clock signal, and a recording clock signal stably synchronous with the wobble signal can be generated.

The above objects of the present invention are
20 also achieved by a data recording clock signal generator that generates a recording clock signal synchronous with a wobble signal used for recording data on an optical disk having a data recording track wobbled by the wobble signal having predetermined frequency components. This
25 data recording clock signal generator comprises:

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a recording clock signal dividing unit that generates a divided clock signal obtained by dividing the frequency of the recording clock signal;

10 a first frequency control signal generating
unit that generates a first frequency control signal
based on the phase difference signal generated by the
phase difference signal generating unit;

a wobble signal cycle counting unit that counts cycles of the divided wobble signal by the cycle of the recording clock signal;

a recording clock signal generating unit that
25 generates the recording clock signal having a frequency

controlled in accordance with the first frequency
control signal when the number of cycles counted by the
wobble signal cycle counting unit is within a
predetermined range, and generates the recording clock
5 signal having a frequency controlled in accordance with
the second frequency control signal when the number of
cycles counted by the wobble signal cycle counting unit
is outside the predetermined range.

With this data recording clock signal
10 generator, prompt locking in the PLL can be carried out
even if the relationship between the frequency of the
wobble signal and the frequency of the recording clock
signal is outside the capture range.

In the above data recording clock signal
15 generator, the recording clock signal generating unit
may generate the recording clock signal having the
frequency controlled in accordance with the first
frequency control signal when the number of cycles
counted by the wobble signal cycle counting unit is
20 within the predetermined range, and generate the
recording clock signal having the frequency controlled
in accordance with the second frequency control signal
when the number of cycles counted by the wobble signal
cycle counting unit is determined to be outside the
25 predetermined range a predetermined consecutive number

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of times.

With this data recording clock signal generator, prompt locking in the PLL can be carried out even if the relationship between the frequency of the wobble signal and the frequency of the recording lock signal is outside the capture range. Also, an unnecessary leading-in operation can be avoided while phase locking is carried out in the PLL.

Other objects and further features of the present invention will become more apparent from the following description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing an example structure of a conventional optical disk driving device;

FIG. 2 illustrates an example structure of a wobbled data recording track on an optical disk;

FIG. 3 is a block diagram showing an example structure of a conventional recording clock generator circuit;

FIG. 4 is a block diagram showing an example structure of an optical disk driving device in accordance with a first embodiment of the present invention;

FIG. 5 is a block diagram showing an example inner structure of the recording clock generator circuit shown in FIG. 4;

FIG. 6 is a block diagram showing an example structure of a frequency divider, a divided clock counter, and a dividing rate setting table shown in FIG. 5;

FIG. 7 is a four-stage timing chart of an operation of the frequency divider;

10 FIGS. 8A to 8G are timing charts of a wobble
signal, a recording clock signal, and a divided clock
signal in a locked steady state where a frequency
dividing condition setting value is "1";

FIG. 9 shows timing charts of various signals
15 in a case where the relationship between the phase of
the wobble signal and the phase of the recording clock
signal is greatly changed;

FIG. 10 shows timing charts of various signals in an operation of a synchronous detection circuit in a case where a bit slip occurs in the optical disk driving device of FIG. 4;

FIG. 11 is a block diagram showing the structure of a recording clock generator circuit in accordance with a fourth embodiment of the present invention;

FIG. 13 is a timing chart of the synchronous detection circuit outputting a phase comparison mask signal;

FIG. 15 is a block diagram showing the inner structure of a frequency comparator of the recording clock generator circuit of FIG. 14; and

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 4 is a block diagram showing an example structure of an optical disk driving device in accordance with a first embodiment of the present invention. In FIG. 4, the same components as in the

optical disk driving device shown in FIG. 1 are denoted by the same reference numerals.

A recording clock generator circuit 4 of this optical disk driving device is a data recording clock
5 signal generator that generates a recording clock signal synchronous with a wobble signal used in data recording on an optical disk having a data recording track wobbled by the wobble signal that has prescribed frequency components.

10 FIG. 5 is a block diagram showing an example inner structure of the recording clock generator circuit 4 shown in FIG. 4. In FIG. 5, the same components as in FIG. 3 are denoted by the same reference numerals.

The recording clock generator circuit 4 is
15 constituted by a so-called PLL (Phase Locked Loop) circuit, and generates a recording clock signal WCLK synchronous with a wobble signal WBL.

A frequency divider 45 outputs a divided clock signal obtained by dividing the frequency of the
20 recording clock signal WCLK in accordance with a frequency dividing rate control signal outputted from a frequency dividing rate setting table 47. The divided clock signal is returned to a phase comparator 41, and is also inputted into a divided clock counter 46.

25 The divided clock counter 46 changes a count

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5 frequency dividing condition setting value of the
divided clock counter 46.

10 table 47.

a 2-bit counter.

15 that is a 3-bit counter, a synchronous SRFF (Set-Reset
Flip-Flop) 455, an inverter 453, and a multiplexer 454
having 3 inputs and one output.

20 B 452, and the synchronous SRFF 455. One cycle of the
recording clock signal will be hereinafter referred to
as "1T".

25 and the counter B 452, respectively.

5 A full-count output (=7) of the counter B 452, which is a signal indicating that the maximum value of the count value of the counter B 452 is "7", is inputted into an output R of the synchronous SRFF 455.

A value selected from values "7", "8", and "9" by the multiplexer 454 is inputted into a data input Di of the counter A 451. When the load input LD becomes active (i.e., the load input LD is "1"), the count value of the counter A 451 is set at "7", "8", or "9".

In the following, an operation of the frequency divider 45 will be described in detail.

25 The counter A 451 and the counter B 452 carry

out a count operation alternately.

The counter A 451 carries out a count operation, starting from an initial value of "7", "8", or "9" selected by the multiplexer 454 until the final value "15". In other words, the counter A 451 counts 7T, 8T, or 9T in one count operation.

The counter B 452 carries out a count operation, starting from the initial value "0" until the final value "7". In other words, the counter B 452 counts 8T in one count operation.

The divided clock is a signal obtained by inverting the output Q of the synchronous SRFF 455 by the inverter 453. Accordingly, the operation of one cycle of the divided clock is the combination of one count operation of the counter A 451 and one count operation of the counter B 452, is equivalent to 15T, 16T, or 17T.

In view of this, the reference frequency dividing rate of the frequency divider 45 is "16", which is allowed to have a variation of ± 1 .

The full-count output (=7) of the counter B 452 is inputted into a count enable input EN of the divided clock counter 46. Accordingly, the divided clock counter 46 adds "1" to the count value every time an operation of one cycle of the divided clock that is

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equivalent to the combination of one count operation of the counter A 451 and one count operation of the counter B 452 is completed.

5 Since the divided clock counter 46 is a 2-bit counter in this embodiment, the count value of the divided clock counter 46 is "0", "1", "2", or "3".

10 The divided clock counter 46 inputs 2-bit count data and 2-bit data as the frequency dividing condition setting value into the frequency dividing rate setting table 47. The frequency dividing rate setting table 47 outputs a frequency dividing rate control signal in accordance with a truth table shown in Table 1, based on the count value and the frequency dividing condition setting value of the divided clock counter 46.

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00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

[Table 1]

Frequency dividing Condition setting Value	divided clock counter value	Sel 7	Sel 8	Sel 9
0	0	0	1	0
	1	0	1	0
	2	0	1	0
	3	0	1	0
1	0	0	0	1
	1	0	1	0
	2	0	1	0
	3	1	0	0
2	0	0	0	1
	1	1	0	0
	2	0	0	1
	3	1	0	0
3	0	0	1	0
	1	0	1	0
	2	0	0	1
	3	1	0	0

5 The frequency dividing rate control signal of the frequency dividing rate setting table 47 is inputted into the multiplexer 454, and the initial value of the counter A 451 is selected in accordance with the frequency dividing rate control signal.

10 When the frequency dividing rate control signal Sel7 is active (i.e., "Sel7" is "1"), the multiplexer 454 selects the value "7". When the frequency dividing rate control signal Sel8 is active

(i.e., "Sel8" is "1"), the multiplexer 454 selects the value "8". When the frequency dividing rate control signal Sel9 is active (i.e., "Sel9" is "1"), the multiplexer 454 selects the value "9".

5 FIG. 7 is a four-stage timing chart of the
operation of the frequency divider 45. Referring to the
four-stage timing chart, the operation of the frequency
divider 45 will be described below in detail.

In the four-stage timing chart of FIG. 7, the top timing chart is an operation timing chart in the case where the frequency dividing condition setting value is "0". The second timing chart from the top is an operation timing chart in the case where the frequency dividing condition setting value is "1". The second timing chart from the bottom is an operation timing chart in the case where the frequency dividing condition setting value is "2". The bottom timing chart is an operation timing chart in the case where the frequency dividing condition setting value is "3".

20 In the horizontal direction of FIG. 7, the
count value of the divided clock counter changes from
"0" to "3". After the operation in the case where the
count value of the divided clock counter is "3" is
completed, the count value of the divided clock counter
25 returns to "0".

First, the operation in the case where the frequency dividing condition setting value is "0" will be described below.

In accordance with the truth table of Table 1,
5 when the frequency dividing condition setting value is
"0", the frequency dividing rate setting table 47 makes
only the frequency dividing rate control signal Sel8
active, regardless of the count value of the divided
clock counter 46.

10 Accordingly, the initial value of the counter A 451 is set at "7" at the start of each divided clock cycle. Thus, the count operation by the counter A 451 is equivalent to 8T in every divided clock cycle, and one cycle of the divided clock is equivalent to 16T.

15 Next, the operation in the case where the
frequency dividing condition setting value is "1" will
be described.

The initial value of the counter A 451 in the divided clock cycle in which the counter value of the divided clock counter 46 is "0" is determined by the output of the multiplexer 454 in the immediately previous divided clock cycle in which the count value of the divided clock counter 46 is "3".

In accordance with the truth table of Table 1,
25 when the frequency dividing condition setting value is

10 Likewise, the divided clock cycle in which the
count value of the divided clock counter 46 is "1" is
equivalent to 15T.

The divided clock cycle in which the count value of the divided clock counter 46 is "3" is equivalent to 16T.

Likewise, when the frequency dividing condition setting value is "2", the number of recording
25 clock cycles in one divided clock cycle repeats the

pattern, "17T 15T 17T 15T , 17T 15T 17T 15T , ...".

When the frequency dividing condition setting value is "3", the number of recording clock cycles in one divided clock cycle repeats the pattern,

5 "17T 16T 16T 15T , 17T 16T 16T 15T , ...".

The number of recording clock cycles in one divided clock cycle is changed as above, the phase of the divided clock varies in the following manner.

When the frequency dividing condition setting
10 value is "0", the recording clock cycles in one divided clock cycle is constantly 16T, which is the reference frequency dividing rate as already mentioned.

The phase comparator 41 picks up the phase of the leading edge of each divided clock signal. Since
15 the divided clock is obtained by inverting the output Q of the synchronous SRFF 455, the phase of the trailing edge of each output Q of the synchronous SRFF 455 is marked in FIG. 7.

When the frequency dividing condition setting
20 value is "1", the divided clock cycle in which the count value of the divided clock counter 46 is "0" is equivalent to 17T. Accordingly, the phase of the trailing edge of the output Q of the synchronous SRFF 455 is delayed by 1T with respect to the reference phase
25 of the divided clock.

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20

25

divided clock.

Referring now to FIGS. 8A to 8G, the relationship between the phase of the wobble signal WBL and the phase of the recording clock signal WCLK in a case where the phase of the divided clock is varied in the above manner will be described below.

The operating time constant of the PLL circuit is generally a cycle longer than a phase comparison cycle. Even if the phase of the divided clock is varied as above, the frequency of the recording clock signal is maintained at a substantially constant value, thereby achieving a locked state in which the average phase of the divided clock signal coincides with the phase of the wobble signal in the steady state.

FIGS. 8A to 8G are timing charts of the wobble signal WBL, the recording clock signal WCLK, and the divided clock signal in the locked steady state where the frequency dividing condition setting value is "1".

FIGS. 8A to 8D show the relationship among the wobble signal WBL, the divided clock signal, and the count value of the divided clock counter 46. FIGS. 8E to 8G show the relationship among the wobble signal WBL, the recording clock signal WCLK, and the divided clock signal, with enlarged views of rising edges on which phase comparison is carried out.

As described above, the average phase of the divided clock signal in the locked steady state coincides with the phase of the wobble signal. Accordingly, the phase of the divided clock with respect to the wobble signal repeats the cycle, "0.75T behind 0.25T ahead 0.25T ahead 0.25T ahead , ...".

Since only the phase of the divided clock is delayed by 1T with respect to the reference phase of the divided clock when the count value of the divided clock counter 46 in the case where the frequency dividing condition setting value is "1", the reference phase of the divided clock is always 0.25T ahead of the phase of the wobble signal. In other words, the phase of the recording clock signal is always 0.25T ahead of the phase of the wobble signal.

Likewise, when the frequency dividing condition setting value is "2" or "3", the phase of the recording clock signal is 0.5T or 0.75T ahead of the phase of the wobble signal, though not shown in the drawings.

In the above manner, the recording clock generator circuit 4 of this embodiment can change the relationship between the wobble signal and the recording clock signal in the range from 0T to 0.75T, 0.25T at a time, in accordance with the frequency dividing

condition setting value of "0" to "3".

Referring now to a timing chart of FIG. 9, a control operation for greatly changing the relationship between the wobble signal and the recording clock signal will be described below.

On the upper half of FIG. 9, an operation timing chart of the frequency divider 45 in the case where the frequency dividing condition setting value is varied from "3" to "0". Here, the timing of changing the frequency dividing condition value from "3" to "0" should coincide with the timing of changing the count value of the divided clock counter 46 from "3" to "0".

As mentioned before, when the frequency dividing condition setting value is "3", the divided clock cycle in which the count value of the divided clock counter 46 is "3" is equivalent to 15T.

Also, when the frequency dividing condition setting value is "0", the divided clock cycle in which the count value of the divided clock counter 46 is "0" is equivalent to 17T, because the initial value of the counter A451 is determined when the frequency dividing value is "3" and the count value of the divided clock counter 46 is "3".

While the frequency dividing condition setting value is "0", the divided clock cycle in which the count

value of the divided clock counter 46 is "1", "2", or "3" is equivalent to $16T$, as mentioned before.

More specifically, in the divided clock cycle immediately after the frequency dividing condition setting value is changed from "3" to "0", an advance phase shift of $1T$ occurs, and this phase shift remains in the following divided clock cycles, unlike in divided clock cycles in which the frequency dividing condition setting value remains "0".

When the frequency dividing condition setting value is changed from "3", with the phase of the recording clock signal is $0.75T$ ahead of the wobble signal, to "0", the phase of the recording clock signal shifts $1T$ ahead of the wobble signal. When the frequency dividing condition setting value is further changed in the order of "1 2 3", the phase of the recording clock signal shifts " $1.25T$ $1.5T$ $1.75T$ " ahead of the wobble signal in the steady state.

The lower half of FIG. 9 shows a timing chart of the operation of the frequency divider in a case where the frequency dividing condition setting value is changed from "0" to "3". Here, the timing for changing the frequency dividing condition setting value from "0" to "3" coincides with the timing for changing the count value of the divided clock counter 46 from "3" to "0".

As mentioned before, when the frequency dividing setting value is "0", the divided clock cycle in which the count value of the divided clock counter 46 is equivalent to 16T.

5 When the frequency dividing setting value is "3", the divided clock cycle in which the count value of the divided clock counter 46 is "0" is equivalent to 16T, because the initial value of the counter A 451 is determined when the frequency dividing condition setting
10 value is "0" and the count value of the divided clock counter 46 is "3".

While the frequency dividing condition setting value is "3", the divided clock cycle in which the count value of the divided clock counter 46 is "1", "2", or
15 "3" is equivalent to 16T, 16T, or 15T, respectively.

More specifically, in the divided clock cycle immediately after the frequency dividing condition value is changed from "0" to "3", a delay phase shift of 1T occurs, and this phase shift remains in the following
20 divided clock cycles, unlike in divided clock cycles in which the frequency dividing condition setting value remains "3".

When the frequency dividing condition setting value is changed from "0", with the phase of the
25 recording clock signal being coincident with the wobble

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signal, to "3", the phase of the recording clock signal shifts $0.25T$ behind the wobble signal. When the frequency dividing condition setting value is further changed in the order of "2 1 0", the phase of the recording clock signal shifts " $0.25T$ $0.5T$ $0.75T$ " behind the wobble signal in the steady state.

In the above manner, the recording clock generator circuit of this embodiment can change the relationship between the wobble signal and the phase of the recording clock signal from $0T$ to $0.75T$, $0.25T$ at a time, depending on the frequency dividing condition setting value in the range of "0" to "3". Furthermore, the recording clock generator circuit of this embodiment can flexibly change the relationship between the wobble signal and the phase of the recording clock signal, $0.25T$ at a time, by increasing the frequency dividing condition setting value in a binary-counter fashion, "3 0 1 2 3, ...", or decreasing the frequency dividing condition setting value in the order of "0 3 2 1 0, ...".

In the recording clock generator circuit of this embodiment, the count length of the divided clock counter 46 is "4", and the repeating cycle of the frequency dividing rate variation of the frequency divider 45 is "4". Accordingly, the relationship

between the phase of the wobble signal and the phase of the recording clock signal is changed $0.25T$ at a time. However, the count length and the repeating cycle of the frequency dividing rate variation can be made greater, so that the relationship between the phase of the wobble signal and the phase of the recording clock signal can be changed a smaller amount at a time.

Next, a recording clock generator circuit in accordance with a second embodiment of the present invention will now be described.

This recording clock generator circuit of the second embodiment has substantially the same structure as shown in FIGS. 5 and 6, and is used as the recording clock generator circuit 4 in the optical disk driving device shown in FIG. 4. However, the functions of the recording clock generator circuit of this embodiment differ from those of the recording clock generator circuit of the first embodiment.

The recording clock generator circuit 4 generates randomly selects a frequency dividing condition setting value by a controller (not shown) every time data is recorded on the optical disk 1. Accordingly, the relationship between the phase of the wobble signal and the phase of the recording clock signal randomly changes every time data recording is

performed on the optical disk 1, so that repeated use of the same recording area on the optical disk can be prevented. Thus, wear of the disk material can be evened and reduced, and the optical disk can be used a greater number of times. Also, since the recording starting point can be randomly changed without the use of an analog delay circuit, the production costs of the optical disk driving device can be reduced.

Next, a recording clock generator circuit in accordance with a third embodiment of the present invention will now be described.

This recording clock generator circuit has the same structure as shown in FIGS. 5 and 6, and is used as the recording clock generator circuit 4 in the optical disk driving device shown in FIG. 4. However, the functions of the recording clock generator circuit of this embodiment are different from those of the first and second embodiments.

Address information and a synchronizing signal are modulated and superimposed on a wobble signal on the optical disk 1, on which data recording is to be performed with the recording clock generated by the recording clock generator circuit 4.

A synchronous detector circuit 5 of the recording clock generator circuit 4 detects the

synchronizing signal superimposed on the wobble signal, and outputs a wobble synchronizing signal. The address decoder 6, on the other hand, detects the address information superimposed on the wobble signal.

5 The data encoder 8 modulates recording data in synchronization with a recording clock signal WCK, and inserts the synchronizing signal in the modulated data. The data encoder 8 also outputs an encoder synchronizing signal at the time of inserting the synchronizing signal.

10 A synchronous detector circuit 11 monitors the timing of the wobble synchronizing signal and the encoder synchronizing signal. In general, when the phase of the wobble signal synchronizes with the phase of the recording clock signal, the timing of the wobble
15 synchronizing signal coincides with the timing of the encoder synchronizing signal. However, if a bit slip occurs in the recording clock generator circuit 4, a phase shift is caused between the wobble signal and the recording clock signal. Accordingly, a timing
20 difference that is equivalent to the bit slip is caused between the wobble synchronizing signal and the encoder synchronizing signal.

 In such a case where a timing difference is caused between the wobble synchronizing signal and the
25 encoder synchronizing signal, the synchronous detector

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circuit 5 changes the frequency dividing condition setting value to be set in the recording clock generator circuit 4 in accordance with the timing difference.

FIG. 10 shows timing charts of various signals in an operation of the synchronous detector circuit 5 in a case where a bit slip occurs in the optical disk driving device of FIG. 4.

In FIG. 10, a bit slip occurs between the second synchronizing signal from the left and the third synchronizing signal from the left, and, as a result, a timing difference is caused between the third wobble synchronizing signal from the left and the third encoder synchronizing signal from the left.

Due to the bit slip, the phase of the recording clock is delayed with respect to the wobble signal, and the wobble synchronizing signal is generated ahead of the generation of the encoder synchronizing signal.

In such a situation, the synchronous detector circuit 5 changes the frequency dividing condition setting value so that the phase of the recording clock signal is advanced to compensate the phase lag caused by the bit slip. By doing so, the phase of the recording clock signal can be advanced $0.25T$ at a time with respect to the wobble signal by increasing the frequency

dividing condition setting value in the binary-counter fashion, "0 1 2 3 0 1, ...".

The synchronous detector circuit 5 continues to change the frequency dividing condition setting value until the timing difference between the wobble synchronizing signal and the encoder synchronizing signal is eliminated. Thus, the phase lag of the recording clock caused by the bit slip can be compensated.

10 In the above manner, the recording clock generator circuit of this embodiment corrects a phase shift between the wobble signal and the recording clock signal even when a bit slip occurs in the recording clock signal with respect to the wobble signal, and the
15 recording data can be restored at a predetermined location.

Next, a recording clock generator circuit in accordance with a fourth embodiment of the present invention will be described below.

20 FIG. 11 is a block diagram showing the structure of the recording clock generator circuit of this embodiment. This recording clock generator circuit has substantially the same structure as the recording clock generator circuit shown in FIG. 3, except that a
25 phase comparison mask signal is inputted into the phase

comparator 41. The recording clock generator circuit of this embodiment is also used as the recording clock generator circuit 4 in the optical disk driving device shown in FIG. 4.

5 Address information and a synchronizing signal are phase-modulated and superimposed on a wobble signal on the optical disk 1, on which data is to be recorded with the recording clock generated by the recording clock generator circuit 4.

10 FIG. 12 shows an example waveform of a phase-modulated wobble signal.

 In the optical disk driving device using the recording clock generator circuit of the fourth embodiment, the synchronous detection circuit 5 detects
15 the synchronizing signal superimposed on the wobble signal, and outputs the phase comparison mask signal to the phase comparator 41 so as to mask detection of the phase difference at any timing close to the timing when the address information or the synchronizing signal is
20 phase-modulated.

 FIG. 13 is a timing chart of the synchronous detection circuit 5 outputting the phase comparison mask signal.

 As shown in FIG. 13, the synchronous detection
25 circuit 5 detects the synchronizing signal superimposed

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reset by an input of the divided wobble pulse. As a result, the register 4013 is loaded with the value obtained by counting the cycles of the divided wobble signal by the cycle of the recording clock signal. When
5 the divided frequency of the clock signal is lower than the frequency of the wobble signal, the count value is also smaller than the frequency of the wobble signal, and when the divided frequency of the clock signal is higher than the frequency of the wobble signal, the
10 count value is also greater than the frequency of the wobble signal.

A data comparator 4014 outputs a Down signal when the count value of the register 4013 is greater than the predetermined value, and outputs an Up signal
15 when the count value of the register 4013 is smaller than the predetermined value. When the count value of the register 4013 is within a predetermined range, the data comparator 4014 makes the switching signal MUX active so as to select the output of the charge pump 42.
20 When the count value of the register 4013 is outside the predetermined range, the data comparator 4014 makes the switching signal MUX inactive so as to select the output of the charge pump 402.

The above predetermined range is equivalent to
25 the capture range of the PLL circuit. Accordingly, when

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In the above manner, prompt phase locking can be performed with the recording clock generator circuit of this embodiment, even when the relationship between the frequency of the wobble signal and the frequency of the recording signal is outside the capture range.

The recording clock generator circuit of this embodiment has substantially the same structure as the recording clock generator circuit shown in FIG. 11, except for the inner structure of the frequency

25 comparator 401. This recording clock generator circuit

is also used as the recording clock generator circuit 4
in the optical disk driving device shown in FIG. 3.

FIG. 16 is a block diagram showing the inner
structure of the frequency comparator 401 of this
5 embodiment.

This frequency comparator 401 comprises a
counter 4015 and a flip-flop 4016, as well as the
counter 4011, the counter 4012, the register 4013, and
the data comparator 4014, which are also provided in the
10 frequency comparator 401 shown in FIG. 15.

When the count value of the register 4013 is
within a predetermined range, the register 4013 makes
the switching signal MUX active. As the switching
signal MUX is made active, the flip-flop 4016 makes
15 another switching signal MUX', which is the output of
the flip-flop 4016 itself, active.

When the count value of the register 4013 is
outside the predetermined range, the data comparator
4014 makes the switching signal MUX inactive, but
20 maintains the switching signal MUX' active.

When the switching signal MUX is inactive, the
counter 4015 adds "1" to the count value every time the
divided wobble pulse is inputted. When the switching
signal MUX is active, on the other hand, the counter
25 4015 resets the count value by the divided wobble pulse.

When the above count value reaches the predetermined value, the counter 4015 outputs a reset signal to the flip-flop 4016, and makes the switching signal MUX' inactive. In this manner, the switching signal MUX' can
5 be made inactive, only when the register 4013 is loaded with the count value outside the predetermined range a predetermined consecutive number of times.

Accordingly, the frequency comparator 401 can be prevented from wrongly judging that the relationship
10 between the frequency of the wobble signal and the frequency of the recording clock is outside the capture range, despite that it is in fact within the capture range.

As described so far, with the recording clock
15 generator circuit of this embodiment, prompt phase locking can be performed, even when the relationship between the frequency of the wobble signal and the frequency of the recording clock signal is outside the capture range. Also, an unnecessary phase pull-in
20 operation can be avoided while the PLL is locked.

The present invention is not limited to the specifically disclosed embodiments, but variations and modifications may be made without departing from the scope of the present invention.

25 The present invention is based on Japanese

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priority application No. 11-207997, filed on July 22, 1999, the entire contents of which are hereby incorporated by reference.

[illegible]

WHAT IS CLAIMED IS:

1. A data recording clock signal generator that generates a recording clock signal synchronous with a wobble signal used for recording data on an optical disk having a data recording track wobbled by the wobble signal having predetermined frequency components,

10 said data recording clock generator comprising:

a wobble signal extracting unit that extracts the wobble signal;

15 a recording clock signal dividing unit that generates a divided clock signal obtained by dividing the frequency of the recording clock signal;

a phase difference signal generating unit that generates a phase difference signal as a result of phase comparison between the wobble signal and the divided clock signal;

20 a frequency control signal generating unit that generates a frequency control signal based on the phase difference signal generated by the phase difference signal generating unit; and

25

5 generator_{*r*}

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3. The data recording clock signal generator
as claimed in claim 1, further comprising:

a synchronous detection unit that detects a
synchronizing signal superimposed on the wobble signal;

5 a synchronous relationship judgment unit that
judges the synchronous relationship between the detected
synchronizing signal and recording data to be recorded
on the optical disk; and

10 a control unit that controls an average value
of the frequency dividing rate set in the recording
clock dividing unit to be greater than the reference
frequency dividing rate when the synchronous
relationship judgment unit judges that the recording
data lags behind the detected synchronizing signal, and
15 also controls the average value of the frequency
dividing rate to be smaller than the reference frequency
dividing rate when the synchronous relationship judgment
unit judges that the recording data is ahead of the
detected synchronizing signal.

20

4. A data recording clock signal generator
25 that generates a recording clock signal synchronous with

5

comprises:

the wobble signal;

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        a wobble signal extracting unit that extracts
the wobble signal;

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a first frequency control signal generating unit that generates a first frequency control signal based on the phase difference signal generated by the phase difference signal generating unit;

10 a wobble signal cycle counting unit that
counts cycles of the divided wobble signal by the cycle
of the recording clock signal;

a recording clock signal generating unit that generates the recording clock signal having a frequency controlled in accordance with the first frequency control signal when the number of cycles counted by the wobble signal cycle counting unit is within a predetermined range, and generates the recording clock signal having a frequency controlled in accordance with the second frequency control signal when the number of cycles counted by the wobble signal cycle counting unit is outside the predetermined range.

6. The data recording clock signal generator
as claimed in claim 5, wherein

the recording clock signal generating unit
generates the recording clock signal having the
5 frequency controlled in accordance with the first
frequency control signal when the number of cycles
counted by the wobble signal cycle counting unit is
within the predetermined range, and generates the
recording clock signal having the frequency controlled
10 in accordance with the second frequency control signal
when the number of cycles counted by the wobble signal
cycle counting unit is determined to be outside the
predetermined range a predetermined consecutive number
of times.

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ABSTRACT OF THE DISCLOSURE

When data recording is performed on an optical disk provided with a data recording track wobbled by a wobble signal having predetermined frequency components, a recording clock generator circuit extracts the wobble signal, generates a divided clock signal obtained by dividing the frequency of a recording clock signal at a frequency dividing rate that is set through predetermined procedures and is different from a reference frequency dividing rate, generates a phase difference signal as a result of a comparison between the phase of the wobble signal and the phase of the divided clock signal, generates a frequency control signal obtained based on the phase difference signal, and then generates a recording clock signal having a frequency controlled in accordance with the frequency control signal.

FIG. 2 PRIOR ART

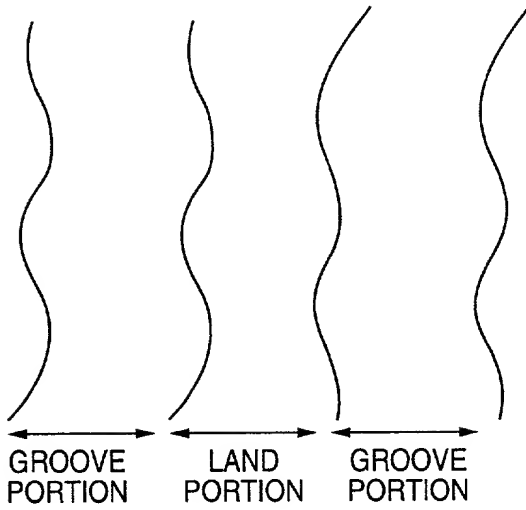


FIG. 3 PRIOR ART

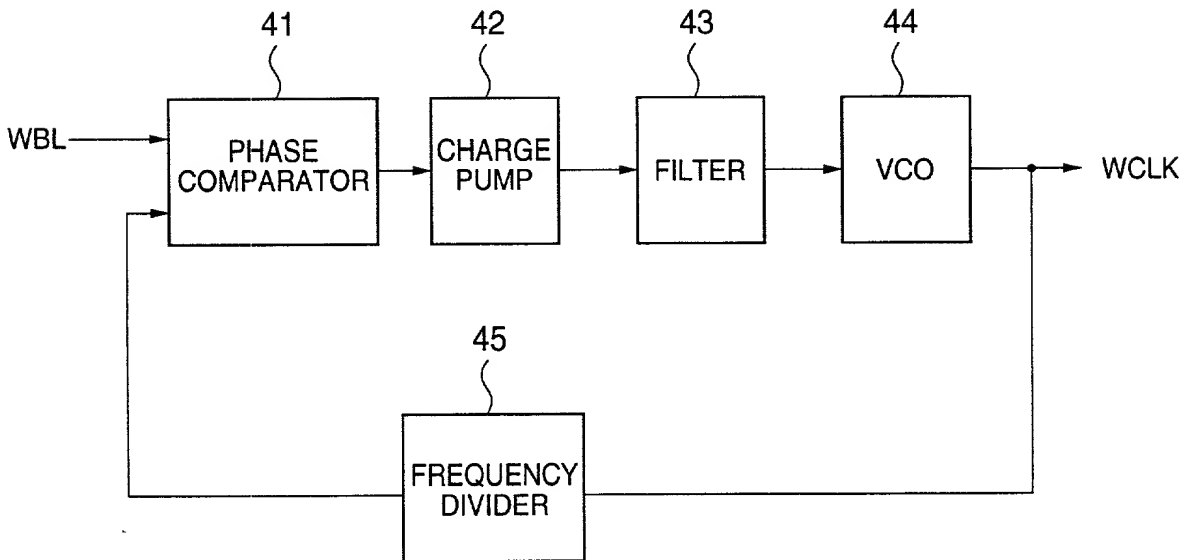


FIG. 4

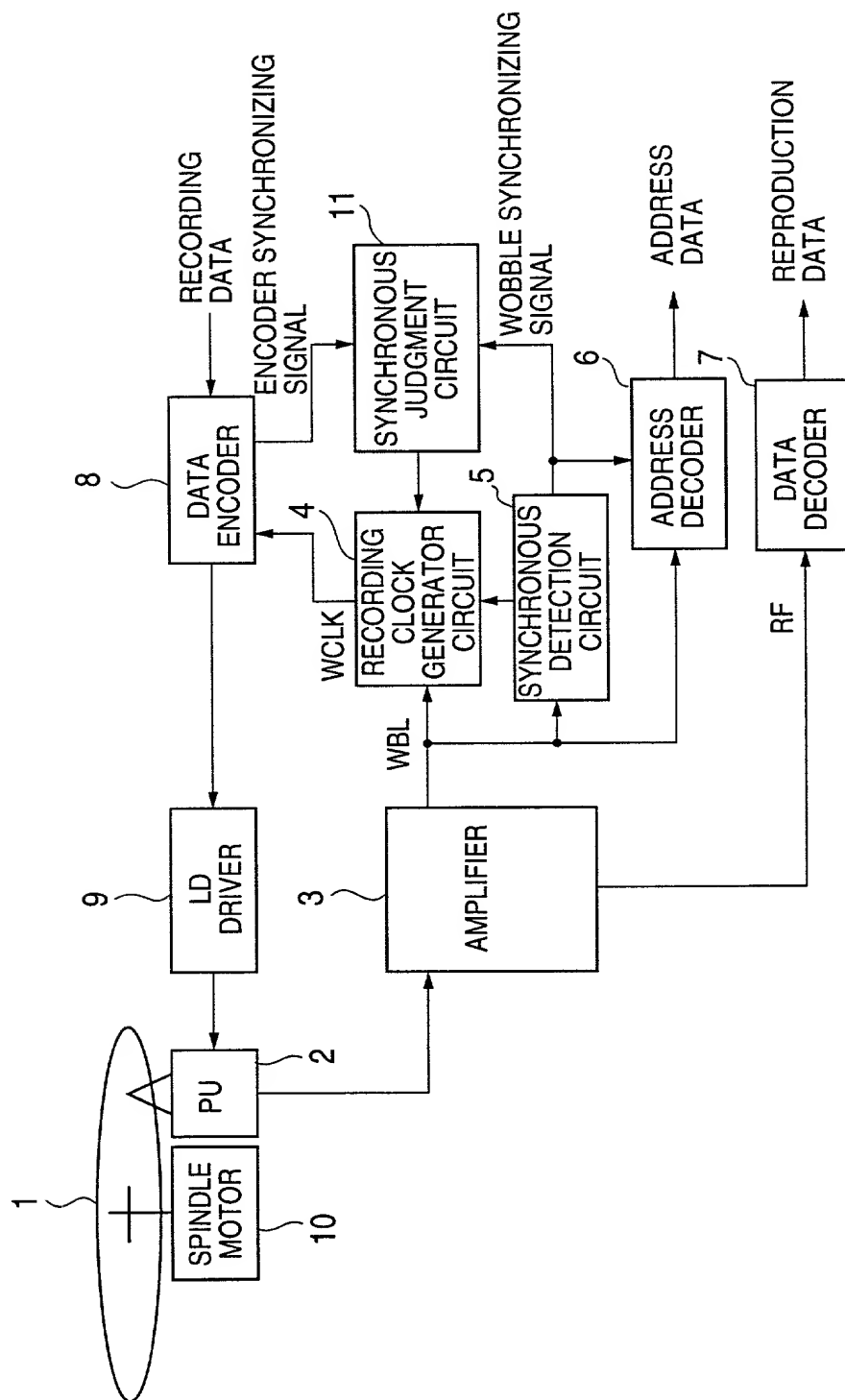
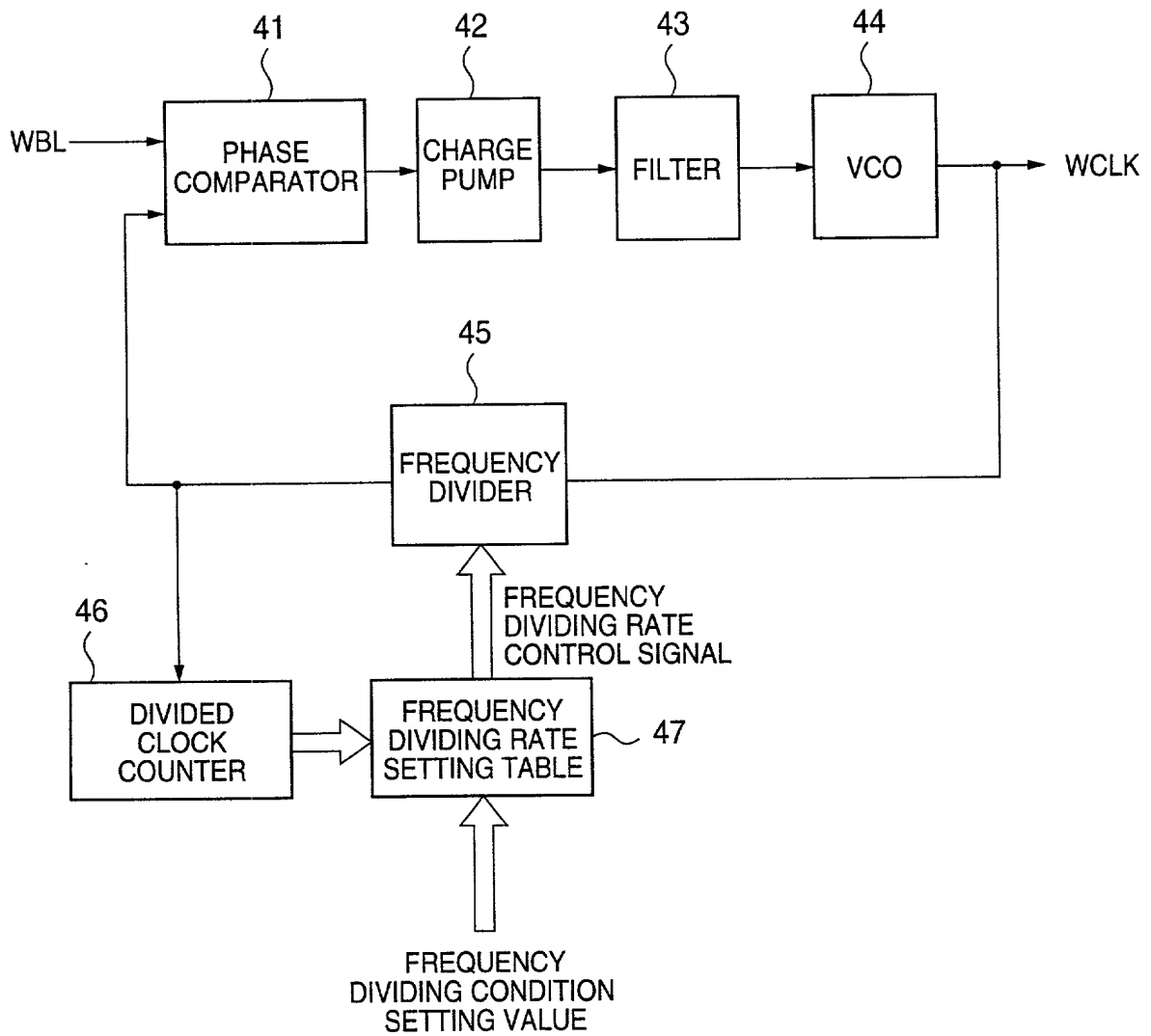


FIG. 5



2. *Chlorophyll a* (Chl *a*) and *Chlorophyll b* (Chl *b*) were determined using the method of Arar and Collins (1987).

2. *Chlorophyll a* (Chl *a*) and *Chlorophyll b* (Chl *b*) were determined using the method of Arar and Collins (1987).

FIG. 8A

FIG. 8B

FIG. 8C

FIG. 8D

FIG. 8E

FIG. 8F

FIG. 8G

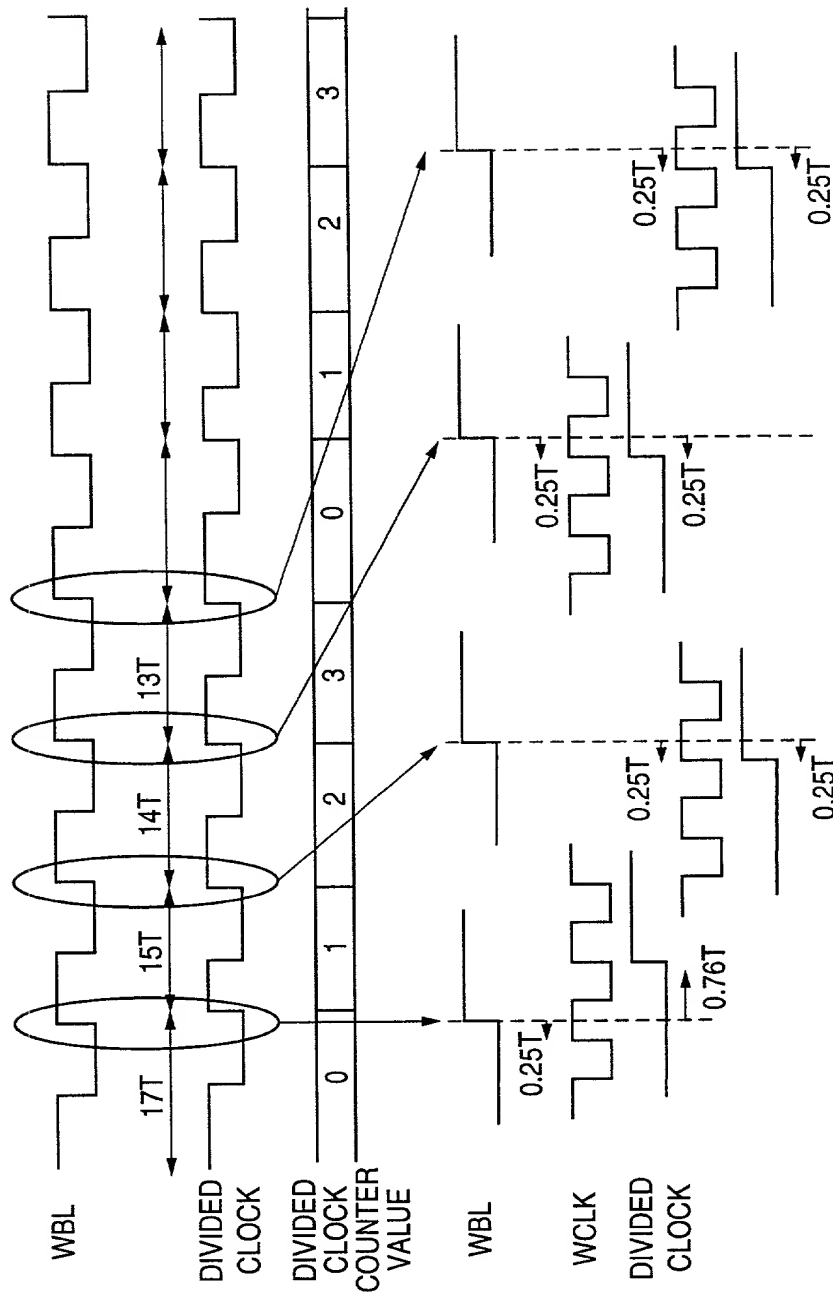


FIG. 9

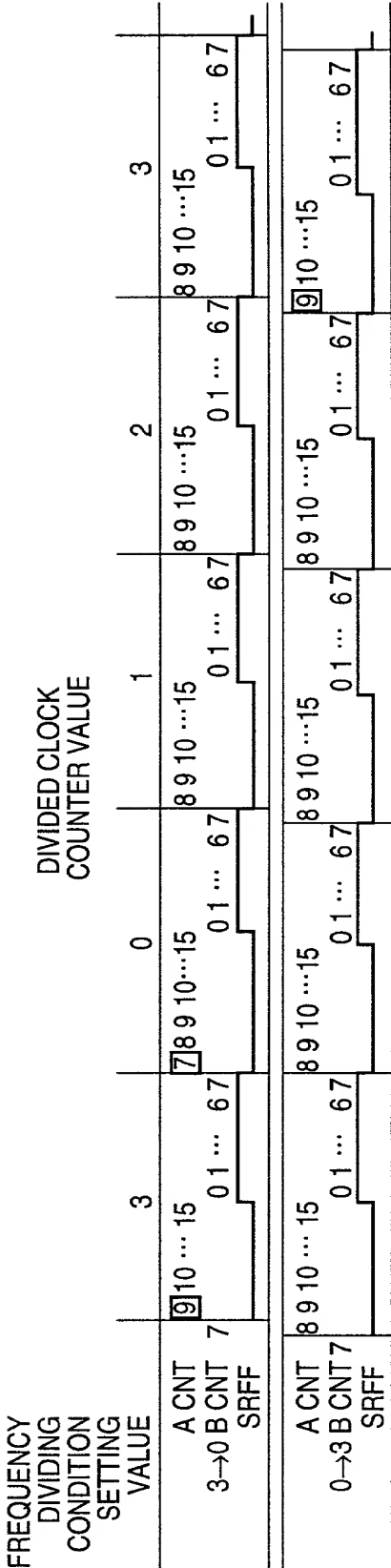


FIG. 10

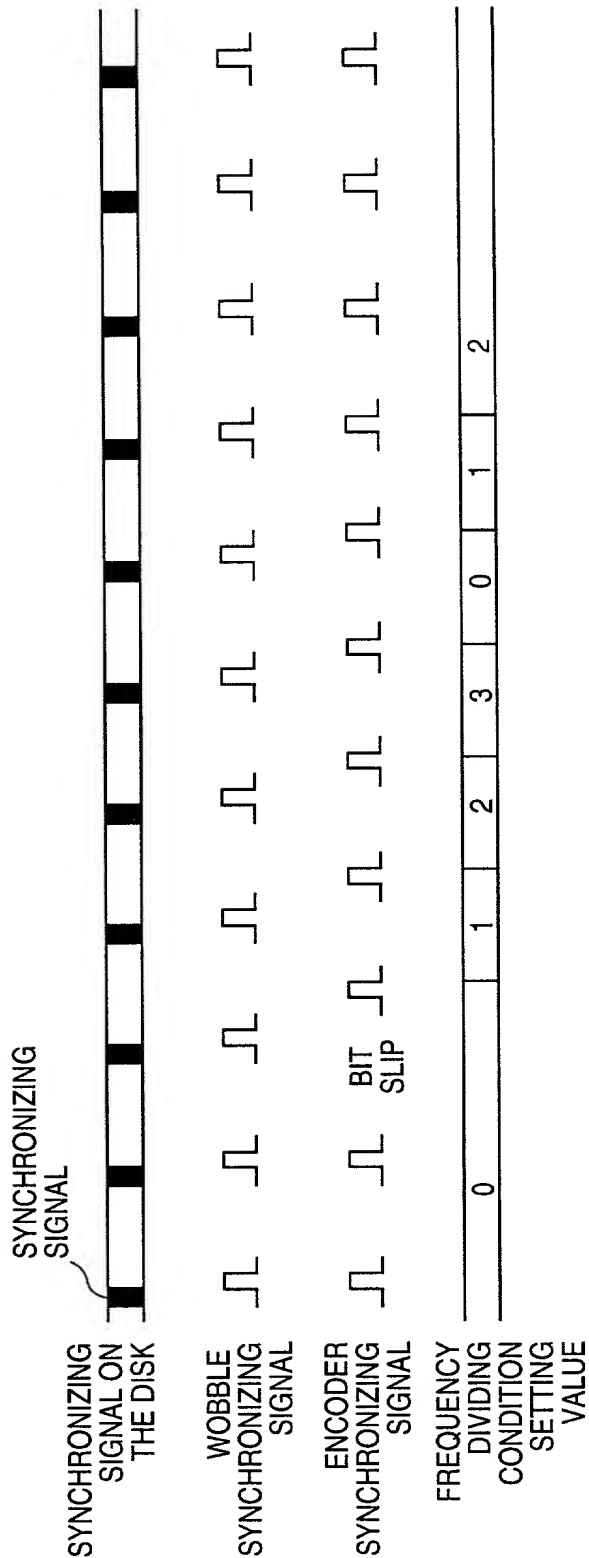


FIG. 11

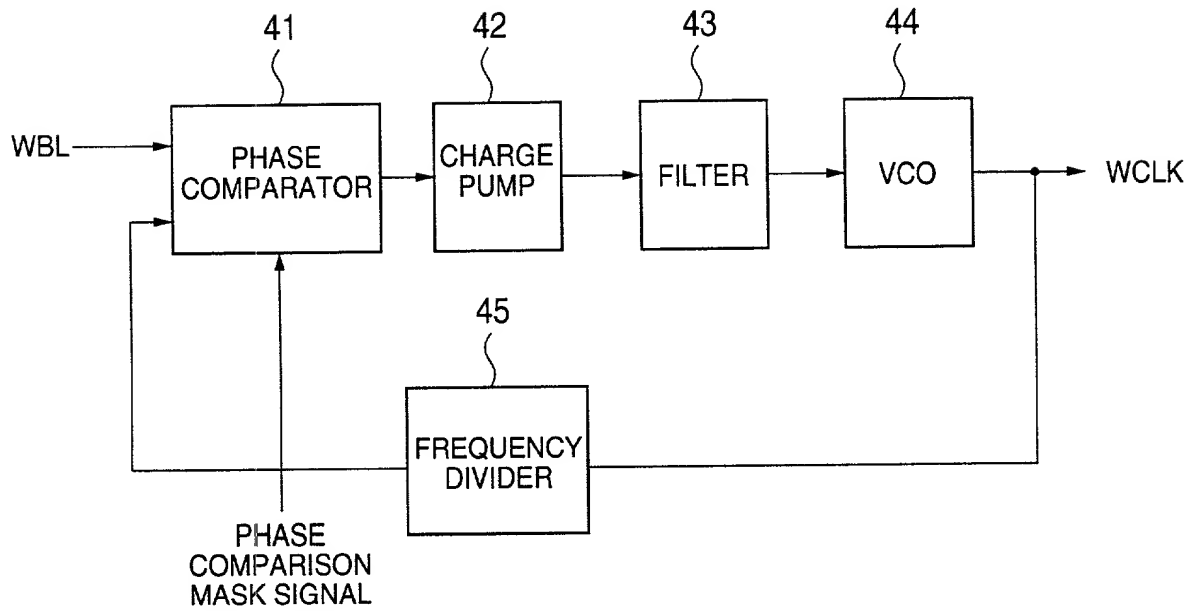


FIG. 12

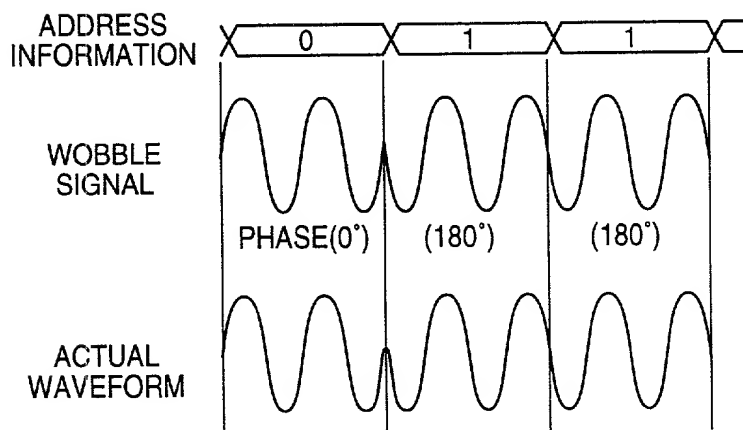


FIG. 13

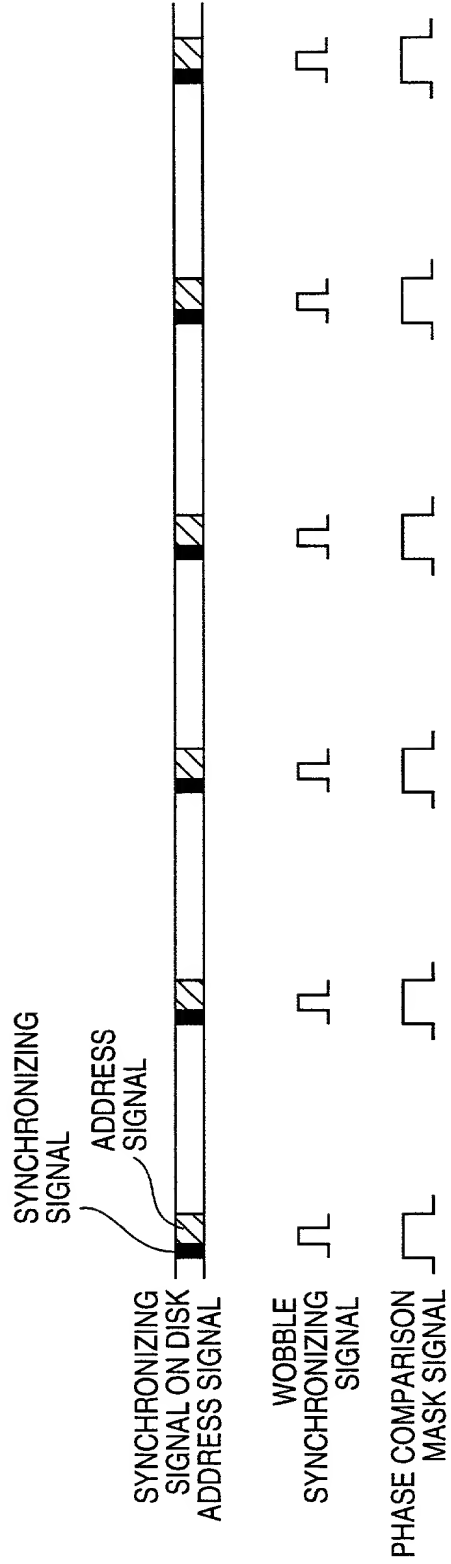


FIG. 15

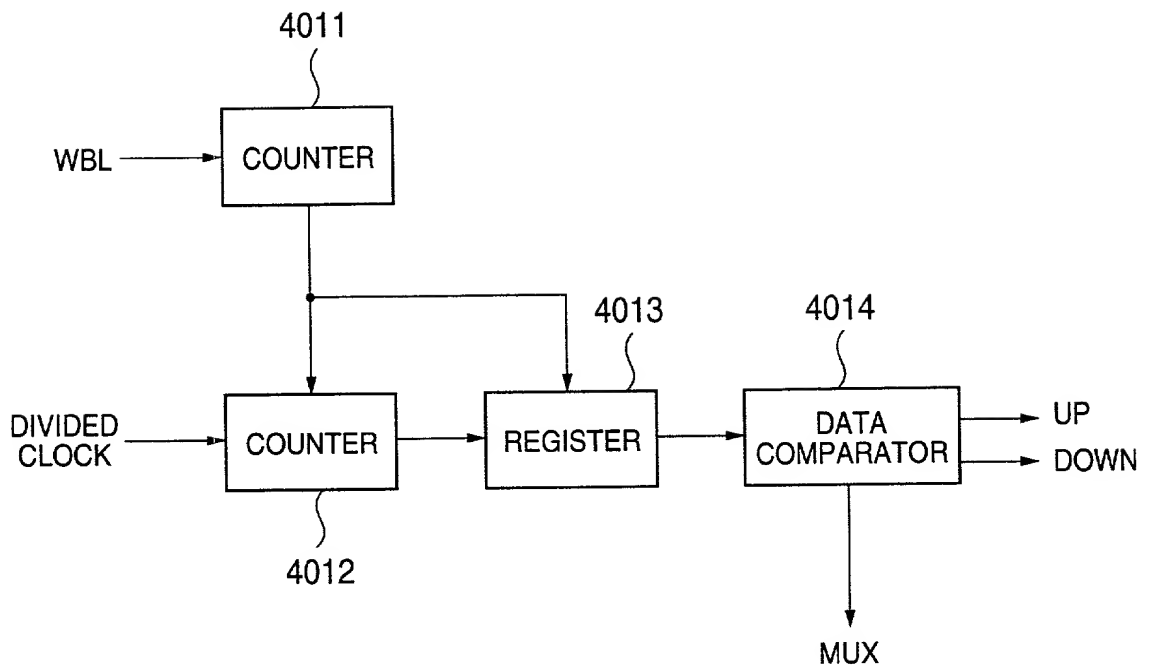
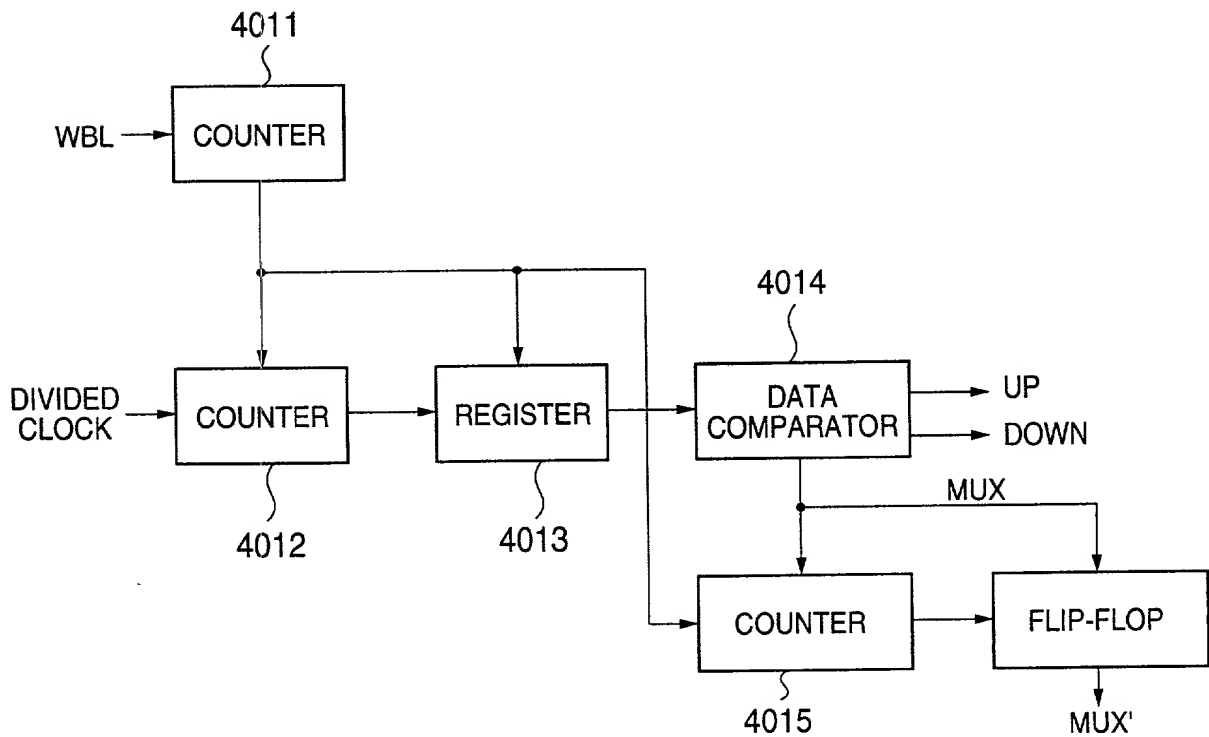


FIG. 16



Docket No.

Declaration and Power of Attorney For Patent Application

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

DATA RECORDING CLOCK SIGNAL GENERATOR

the specification of which

(check one)

☒ is attached hereto.

☐ was filed on _____ as United States Application No. or PCT International

Application Number _____

and was amended on _____

(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

Priority Not Claimed

Patent Application
No. 11-207997

Japan

22/July/1999

☐

(Number)

(Country)

(Day/Month/Year Filed)

☐

(Number)

(Country)

(Day/Month/Year Filed)

☐

(Number)

(Country)

(Day/Month/Year Filed)

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

(Application Serial No.)

(Filing Date)

(Application Serial No.)

(Filing Date)

(Application Serial No.)

(Filing Date)

I hereby claim the benefit under 35 U. S. C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C. F. R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

(Application Serial No.)

(Filing Date)

(Status)
(patented, pending, abandoned)

(Application Serial No.)

(Filing Date)

(Status)
(patented, pending, abandoned)

(Application Serial No.)

(Filing Date)

(Status)
(patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

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Second inventor's signature	Date
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